Knowledge/Data Mining, Assessment and Forecasting of Ground Military Vehicle Technologies

Key-Note Speech

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@

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Key-Note Speech's Outline

- National Automotive Center (NAC) & Tank Automotive Research, Development and Engineering Center (TARDEC) Relationship.
- NAC/TARDECs Technology Thrust Areas
- R & D funding decisions should be based on a thorough scientific analyses of world-wide research in several scientific disciplines.
- Robotics Case-Study
- Innovation required when a solution to a technical requirement adversely affects another.
- Inventive Principles with many examples.
- My Personal Innovations & Thrills

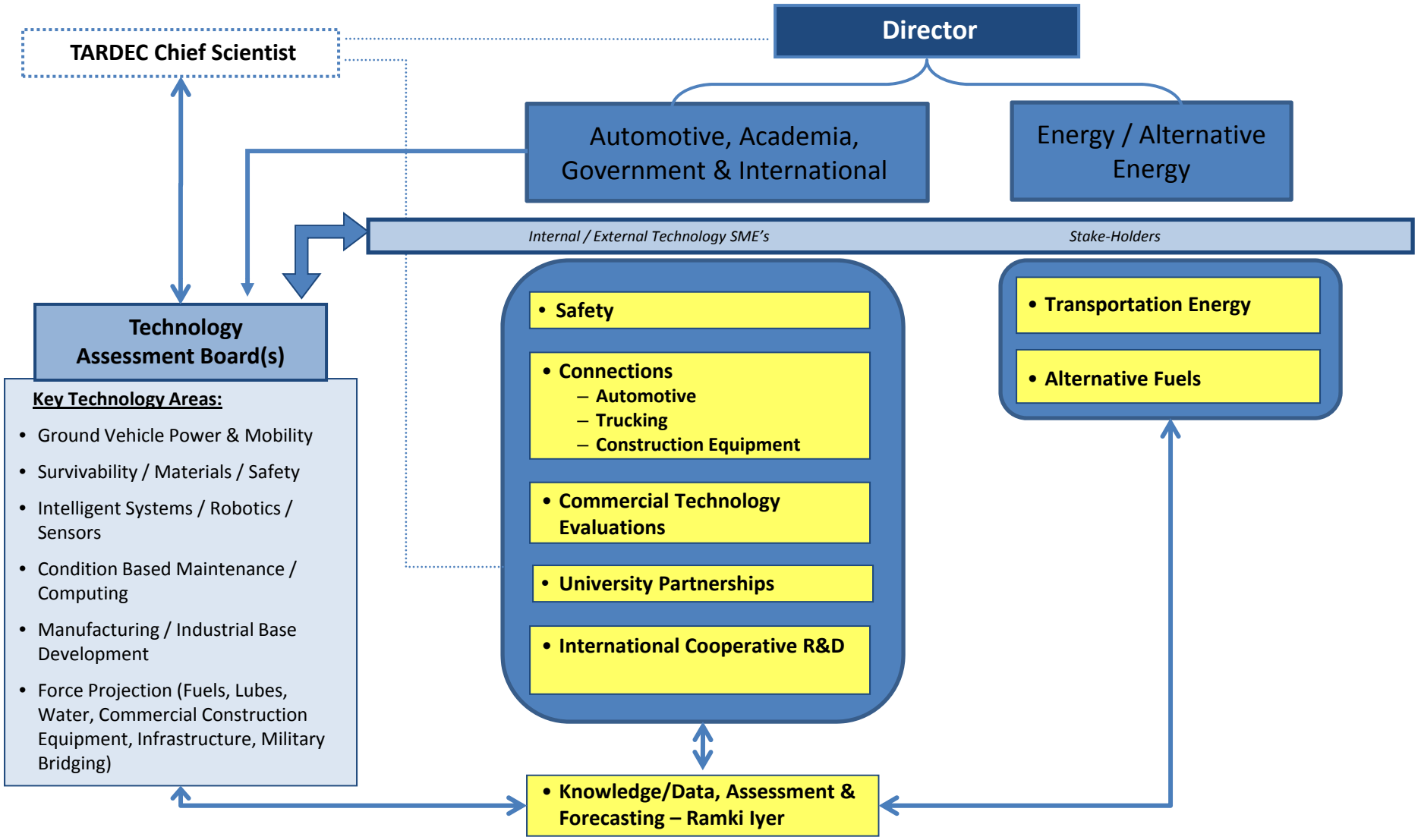
Key-Note Speech's Outline (Continued)

- Challenges to Mine, Assess and Forecast Technology - Information Overload.
- Methods to Mine, Assess and Forecast Technology
  - DELPHI
  - Software
- NACs Strategic Plan to implement Mine, Assess & Forecast Technologies.
  - Combination of Delphi & Software Approaches
  - Technology Assessment Boards (TABs)
- TAB Case Study for Miniaturized Superconducting Antenna
- Knowledge Mining, Assessment and Forecasting Implementation Challenges.
- Mitigation Strategies to overcome Implementation Challenges
- Current Status
- Questions

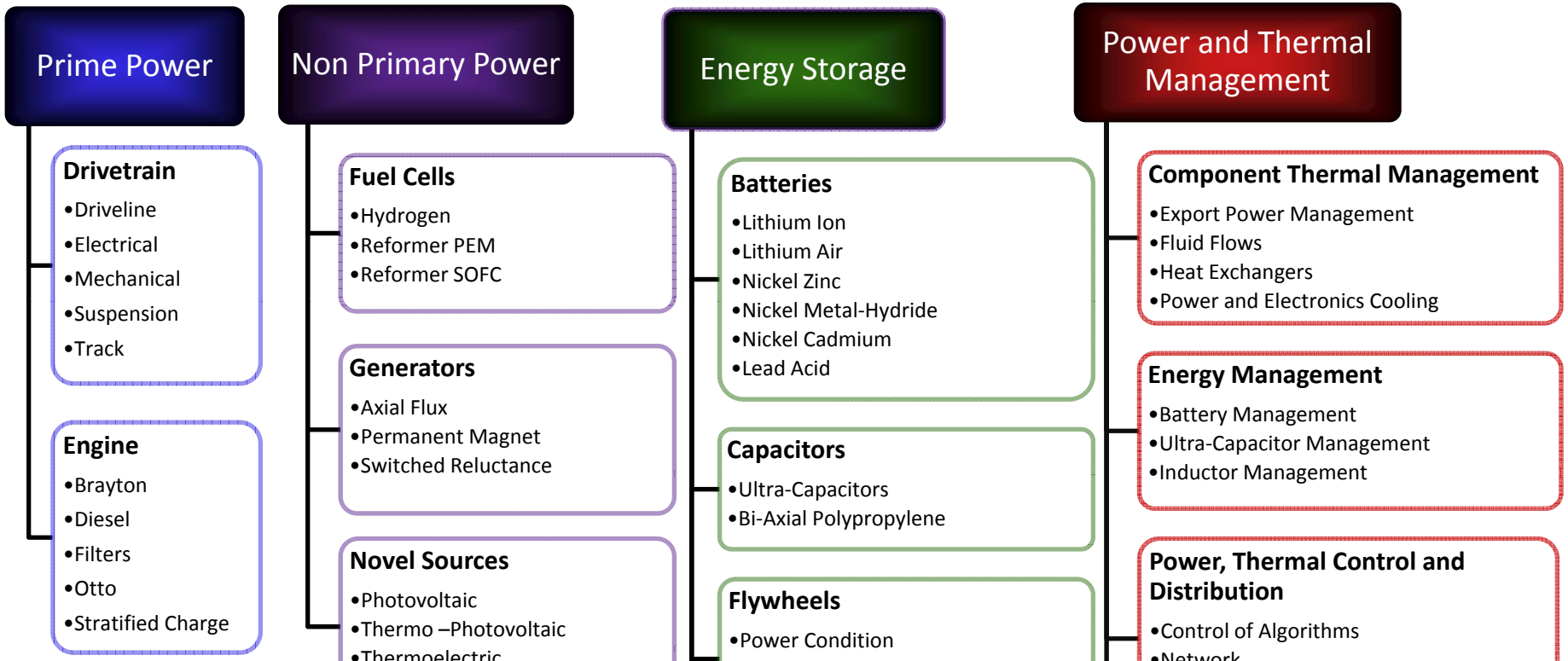
NAC – TARDEC Relationship

NAC is the window between TARDEC and World-wide Industry / Academia for Thrust Technologies of benefit to the War-fighter and the Commercial World.

NAC-TARDECs Technology Thrust Areas



Power and Energy Technology Thrust Area's Taxonomy



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R & D Funding needs to be based on thorough World-wide Analyses of Information

- Army's Requirement
  - Gadget to defuse bombs in multi-storied buildings
- Scientist John Doe proposes an obvious solution
  - 4 Legged robot with the capability of
  - Video Camera
  - Chemical/Biological Sensors
  - Climbing, Turning & Collision Avoiding Capabilities; etc.
- Funding Sought - $4m across 4 years
- Should the above project be funded?
  - No, for the time being, since enough base-line research not conducted

R & D Funding needs to be based on thorough World-wide Analyses of Information

- **Recall network news 2 or 3 years ago**
  - China had developed a 2-legged robot to deliver beverages as desired by patients
  - 2-legged robot apparently comprised
  - Kinematics, Control System, Electronics, Power, etc.
  - Recent research in exo-skeleton sensors exploited Micro-Electro Mechanical Sensors (MEMS)
- Above technologies can be adapted for the bomb de-fusing application by collaborating with China
- Also use the MEMS concept

R & D Funding needs to be based on thorough World-wide Analyses of Information

- **Result**
  - Reduced development risk
  - Reduced development time & cost
  - Frees up valuable $s for other research
  - Win-Win Situation
- **Collaboration**
  - Promotes Innovation
  - Achieves a balance between opposing ideals of **social community and free enterprise**

Innovation Challenges

Information Explosion:

- Over 1,000 World-wide R & D Databases in different languages
- Over 33 million+ patents
- Conclusion
  - Innovation Required

Innovation Required despite Information Explosion

- **Technical problem**
  - Requirement
    - More payload carrying capacity on vehicle
  - Obvious Solution
    - Increase section thickness
- **Result**
  - Increased vehicle weight adversely affects mobility
- **Required Approach**
  - Out-of-the-box thinking required to innovate
  - Solution in one scientific area solves a problem in another

Innovation Required despite Information Explosion

- **Innovative Solution Example**
  - Army Tank's Turbine engine's Metal Blades pitting due to operation in the desert
  - Apparent thought – Use ceramics that are extensively used in armor
  - Armor Ceramics – thick, heavy, joining problem with metal
- Thermal spray ceramics manufacturing of **micro-electronics** industry successfully solved the blade pitting problem – Excellent adhesion properties of thin films
- **Conclusion**
  - Current problems in one scientific area easily solvable by applying concept used in another

Theory of Inventive Solutions - Motivation

- Recurrent problems & solutions across sciences
- Recurrent technology evolution patterns
- Innovation in one technology inspired from another

- Conclusion
  - Out-of-the-box thinking required to innovate
  - Solution in one science area solves a problem in another
  - Turbine blade pitting problem - one example

Theory of Inventive Solutions

- Another Example
  - Field curing of polymer composites using paramagnetic heating characteristics of embedded ferro-magnetic nano-powders
    - Accomplishes controlled field curing compared to induction heating
  - Out-of-the-box thinking – Use paramagnetic properties to only kill cancerous cells

Theory of Inventive reasoning motivates out-of-the-box thinking to deduce solutions

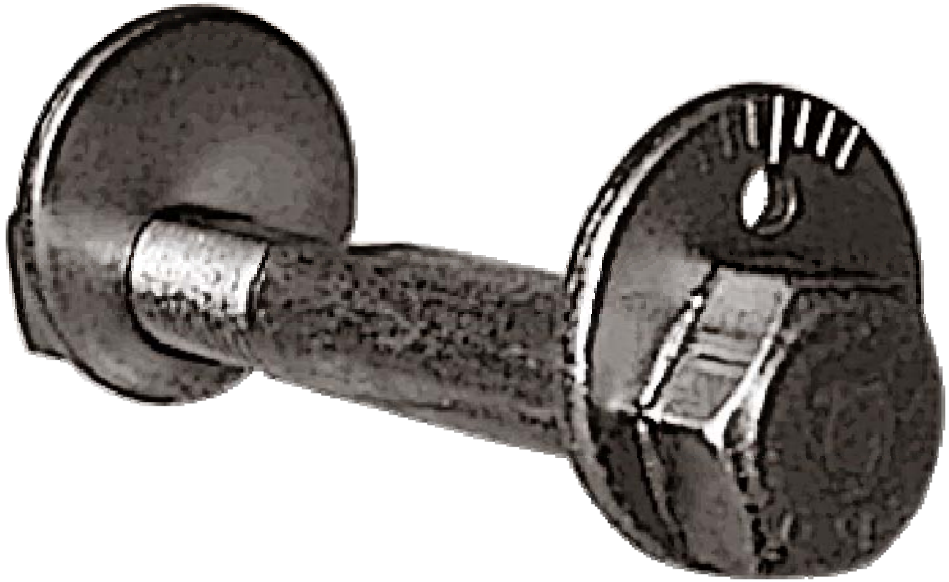
Some Principles that Motivate Innovative Thinking

1. **Partition**
   - Project work break down structure
   - Drawings from overall assembly to components to parts
   - Net-worked PCs versus Super-Computers
   - Modular military bridges
2. **Removal**
   - Extract infected tooth to avoid spreading infection
   - Electrical fuse
   - Structural fuse
   - Inexpensive and easy to replace component
     - Use weaker material so a component fails before critical failure of system.
     - Easier to replace a fuse, than to replace a system

Some Principles that Motivate Innovative Thinking (Continued)

3. **Change Macro/Micro Compositions**
   - Orthotropy / Anisotropy instead of Isotropy
     - Polymer composites with oriented carbon, glass, metal fibers instead of only metals
       - Reduced Weight

4. **Asymmetry**
   - Eccentric Bolt



Some Principles that Motivate Innovative Thinking (Continued)

5. **Integration**
   - Peer-to-Peer (P2P) Networking Protocol
     - Direct connection to PCs across the world using the internet
     - Provides increased computing power – avoids costly ownership of a data processing center

6. **Universality**
   - One size fastener in a military system
     - Results in volume procurement price discount
     - Ability to retain a smaller inventory stock

7. **Nesting (Matryoshka)**
   - Nested Dolls – Inspires children, ***even me!!*** ☺
   - Telescoping cranes, Mobile Antennae, Mobile Missile Launcher

Some Principles that Motivate Innovative Thinking (Continued)

8. **Counter-moment**
   - To resist large lateral deflection of earth-quake forces in multi-story buildings – Japan's success.
   - To mechanically launch/retrieve military bridge

9. **Prior Anti-Action**
   - Pre-stressed Concrete
   - Lead Apron – X-ray
   - Health Care – Yearly Physical

10. **Pre-action**
    - Partially cured prepreg
    - Assembly line manufacture for automobiles inspired by the watch making industry.
    - Sterilized medical instruments

Some Principles that Motivate Innovative Thinking (Continued)

11. **Energy Absorption**
    - Seat-Belts in automobiles, aircraft
    - Air-bags in automobiles
    - Helmets and armor
    - Principle
      - Energy = Load * Displacement
      - Small Load ⇨ Large Displacement
      - Large Load ⇨ Small Displacement

12. **Uniform Potential**
    - To reduce load to lift / lower - Pulleys
    - Rollers on luggage
    - Rollerblading to work

Some Principles that Motivate Innovative Thinking (Continued)

13. **Invert the process**
    - Pultruded polymer composites instead of extrusion as used in Al
    - Heat treat fabricated aluminum structure in annealed condition instead of heat treat components prior to assembly fabrication.
14. **Curvature instead of flat**
    - Arch structure induces in-plane and not out-of-plane forces
    - Geodesic dome – R. Buckminister Fuller, Inventor
    - Umbrella Design – change to hemisphere to a small plastic window to enable the ability to see and also use in rain/sun.
      (My innovation when I was 18 years old - my friends shot it down).
15. **Partial Solution**
    - Classic approach in risk management of technology
      – 70% solution today is better than the delayed 100% solution
    - Software Patches very common
      – Increased universal usage improves product compared to limited beta-testing.

Some Principles that Motivate Innovative Thinking (Continued)

16. **Add Dimension**
    - Multi-CD player placed in vehicles, versus a single CD player
    - 7.1 surround sound versus 2.0 stereo system
    - Apartment buildings versus single-family homes
    - 64bit CPU processors versus 32bit processors, depending on application.
17. **Vibration**
    - Vibrating shaving razor blade
    - Electric carving knife with vibrating blade
    - Vibrating tooth brush
    - Reclining chair with variable vibration speeds
18. **Periodic Action**
    - How real is real time?... Nano-second, micro-second, etc.
    - In structural health, should it be monitored
      – Once a day or immediately alert of failure
    - Health Care – Emergency call button

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Some Principles that Motivate Innovative Thinking (Continued)

19. **Continuity of activities**
    - CPM / PERT network for a project has activities on critical path and others not on the critical path.
    - Activities on critical path do not have float
    - Move resources of activities from non-critical path to those on the critical path.
    - Condition Based Maintenance (CBM)
      – System redundancy with two controllers operating in parallel
      – If one controller fails, the second controller is fully capable of seamlessly receiving control.

20. **Waste management for useful production**
    - Dung to generate Methane
    - Human Urine to potable water

Some Principles that Motivate Innovative Thinking (Continued)

21. **Reverse Action**
    - Magnetostrictive materials traditionally used as robotic actuator
      – Applied electro-magnetic field translates to a mechanical force
    - Conceived a concept to powderize magnetostrictive rods and introduce them into a slurry, to monitor fatigue cracks – Acts as a sensor.

22. **Skipping**
    - Friction stir welding almost eliminates HAZ (no electrode)
    - Water-jet cutting

23. **Feedback – Cross Check**
    - Amend management measure from budget variance to customer satisfaction.

Some Principles that Motivate Innovative Thinking (Continued)

24. **Intermediate Steps**
    - Dabbas (Food Containers) change multiple hands in reliable supply chain

25. **Self-Service**
    - Pumping gas – reduces cost
    - Buffet concept
    - Toll-paying – Traffic moves fast
    - Money in buses - eliminates the conductor

26. **Mimicking (Replicate Process)**
    - Video conferencing – reduces cost
    - Satellite imaging instead of ground survey

Some Principles that Motivate Innovative Thinking (Continued)

27. **Short living / Degradation**
    - Recycle paper, cans, diapers
    - Compost
28. **Exploit physics**
    - Control heat of resin curing through embedded ferro-magnetic particles, instead of non-controllable induction heating.
    - Use of high-frequency sound waves, to keep dogs away versus using a physical fence.
29. **Use pneumatics/hydraulics instead of solids**
    - Shoe in-soles with silicon padding
    - Airbags in automobiles
    - Inflatable structures – tents, fortification, Mars Pathfinder spacecraft.

Some Principles that Motivate Innovative Thinking (Continued)

30. **Flexible shields and thin film**
    - Reconfigurable aircraft wing to reduce drag - Morphing
    - Use shape memory alloys, polymers, miniature hydraulics
31. **Porous Materials**
    - Drill holes in solid to reduce weight
    - Aerate lawn to improve growth
    - Cigarette Filters
    - Store water in mud pots to keep it cold, if no refrigeration
    - Mosquito nets to enable breathing
32. **Chameleon - Principle of changing color**
    - Litmus paper
    - Changing color of soldier uniform – Commercial T-shirts
    - Energy saving bulbs change low to bright light over time

Some Principles that Motivate Innovative Thinking (Continued)

33. **Homogeneity**
    - Polymer composites fabrication with chopped strand mat reinforcement yields light weight, isotropic properties.
    - Nano-material embedded composites – a hot research topic, e.g. clay for fire resistance, carbon nano-tubes for strength/stiffness.
    - Make a diamond cutting tool using diamonds

34. **Discard and recover**
    - Design portions of an object that are discarded after its function is fulfilled.
    - Antibiotics in dissolving, but a benign capsule
    - Dunk noodles from boiling water into cold water
      – To avoid over-cooking
      – To remove the excess starch

Some Principles that Motivate Innovative Thinking (Continued)

35. **Change physical state**
    - Shape Memory Alloys (SMA) change from Martensitic to Austenitic condition and shape at transition temperature – Application: fasteners.
    - Shape Memory Polymers (SMP)
      – Energy absorbing fasteners
    - Heat ferro-magnetic particles through a magnetic field to a para-magnetic constant state temperature instead of non-controllable induction heating.

36. **Exploit Phase Transition**
    - SMA and SMP
    - Award contracts in increments to reduce risks
    - Hannibal, when attacking Rome, poured water over huge blocking rocks at night that broke into small pieces due to freezing phenomenon.

Some Principles that Motivate Innovative Thinking (Continued)

37. **Thermal Expansion**
    - SMA joints to join pipeline segments – No thread machining
38. **Strong Oxidants**
    - Hyper-baric Chamber
      - Decompression for hit air force pilots
      - Recompression for underwater divers
      - To cure cancer affected mouth
      - To aid healing process in severely burned patients
39. **Inert Environment**
    - Use argon/helium environment to prevent Al. Oxidation while welding.
40. **Composite Materials**
    - Infrastructure – Bridge Decks
      - Carbon instead of steel reinforcement to avoid corrosion problem
      - Wrap-around reinforced concrete pier to resist seismic failure
      - Military composite bridges

COMPOSITE
ARMY
BRIDGE

Some Principles that Motivate Innovative Thinking (Continued)

- Just finished giving Multi-disciplinary examples of innovation principles
- Think out-of-the-box for innovation

Let us now think:

- Beyond the principles presented
- Personal past innovations

Beyond the Theory of Inventive Reasoning

Exploit material phenomenon

Innovation:

- Use shape memory trained alloy insert
- Under transition temperature
  - Insert behaves as a Martensitic passive damper (huge elongation)
  - When temperature increases to transition temperature
  - Changes SMA to Austenitic phase
    - huge strength/stiffness increase
  - Insert wants to change shape but is prevented due to locking torque.
- Result: Smart Fastener
  - So think ***BEYOND*** the principles of the Theory of Inventive reasoning presented

Beyond the Theory of Inventive Reasoning

- Many times innovation is through serendipity
  - SMA insert in fastener always split while machining
  - Behaved better after the break – Increased energy absorption
- Serendipity element in finite element analysis

Beyond the Theory of Inventive Reasoning

- Observe around, with the problem to be solved in mind
  - Rail/Wagons assembly process during shunting

  - Motivated me to conceive and implement an automatic tension resistant locking joint for military bridge while being cantilever launched.

Beyond the Theory of Inventive Reasoning

- Stand on others' shoulders to better scientific discoveries

  - A physicist friend of mine showed me a Scanning Electron Micrograph of some conical growths with whiskers on plasma subjected solid graphite.

  - I conceived the idea to use the above phenomenon to develop growths on carbon fibers, mats – Buckytubes.
    - Improved intra and interlaminar strength and stiffness properties, especially compression.

Beyond the Theory of Inventive Reasoning

- Collaborate / share your knowledge with others
  - My carbon buckytube when shared with Prof. Thomas Hahn a stalwart in composites for the last 50 years (I met him 20 years ago).
  - Ramki: “In all my 25+ years, have never seen as innovation like yours. Incidentally, it also improves transverse intra and interlaminar thermal **conductivity** problem.

Beyond the Theory of Inventive Reasoning

- Exactly understand what is to be gleaned
  - Humongous data
    - Health monitoring of vehicles, infrastructure, humans.
    - Frequently used phrase:
      “Accurately and Reliably monitor in real-time.”

  Issues:
  - “Accurately and reliably monitor”
    - How accurate is accurate?
    - How reliable is reliable?
  - Monitor in real-time
    - Is real-time a nanosecond, microsecond, etc?

Beyond the Theory of Inventive Reasoning

- Approach to thinking and finding a solution
  - Accurate and Reliable
    - Compare experimental results with modeling and simulation predications to assess accuracy and reliability.
  - Real-time
    - Motivation for solution ⇨ Bandwidth, Analysis
    - For an aircraft, ship, bridge
      - Set benchmarks for structural safety
      - Do not care if threshold not exceeded
      - Require data transmission once / day, is if no problem but immediately if a problem occurs.

Beyond the Theory of Inventive Reasoning

- Health of human beings, health care innovation
  - Aging human seniors with problems living alone, at their homes.
  - When they feel any concerned sign of discomfort (like chest-pain).
    - They press a button, that wirelessly calls their son/daughter at work via their cell phone.

Beyond the Theory of Inventive Reasoning

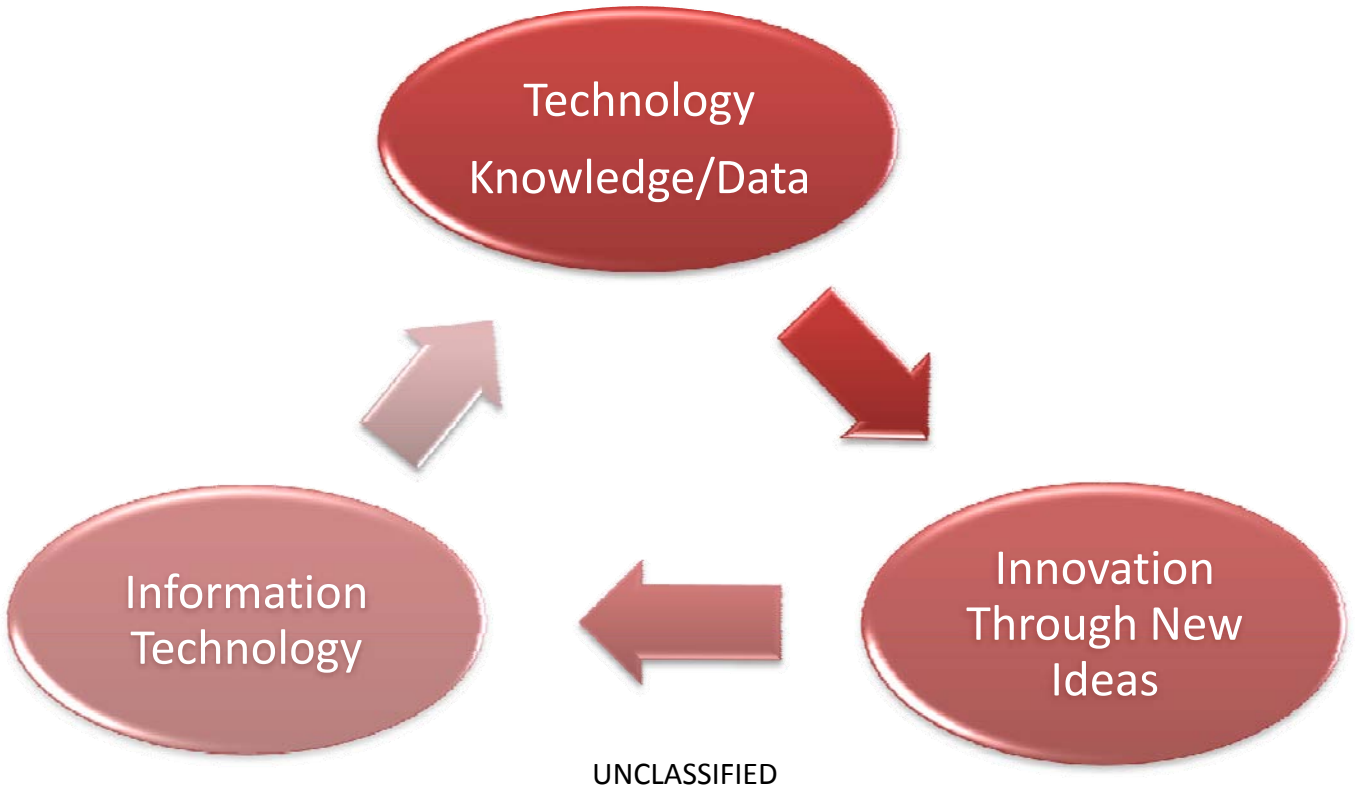
A fantastic world, that we live in – Is it not?

Next Motivation:

- All said and done, beyond the inventive reasoning presented
- How do we tackle technological information overload at on organizational level?

Technology Data/Knowledge Mining, Assessment, and Forecast Method

- DELPHI
- COTS Software Approach



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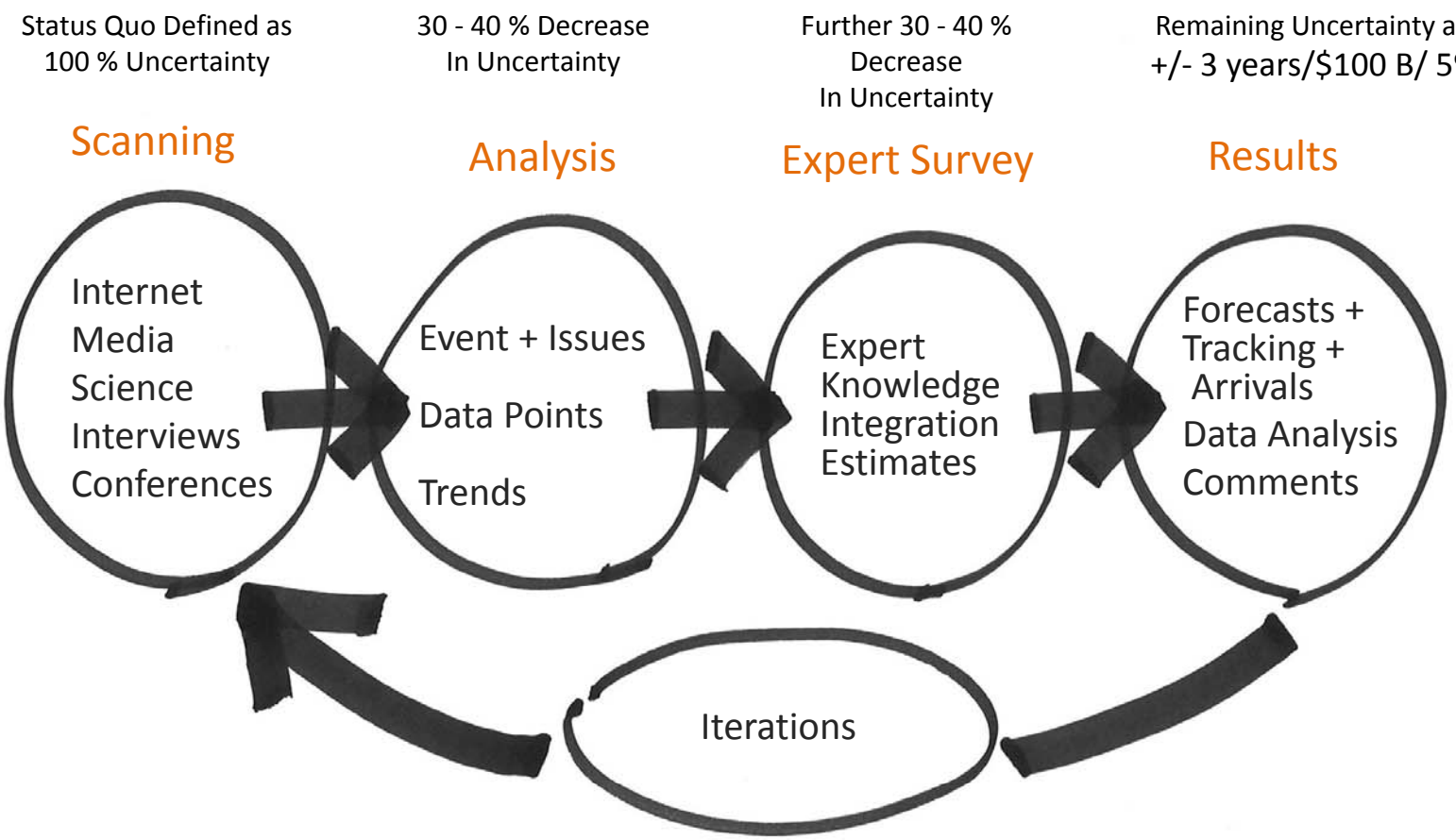
Delphi Method

- Group of experts' opinions sought on technologies
- Technology Examples
  - Fuel Cells
  - Transportation, including space travel
  - Nano-material
  - Cancer – Cure
  - Others
- The Interaction of Groups through the Internet Predict
  - Market Share - % Case, Maturation year
  - Technology Risks

Acknowledgement – Dr. W. Halal

Flow Chart of Research Forecasting System

"Best Possible Answers to Tough Questions"



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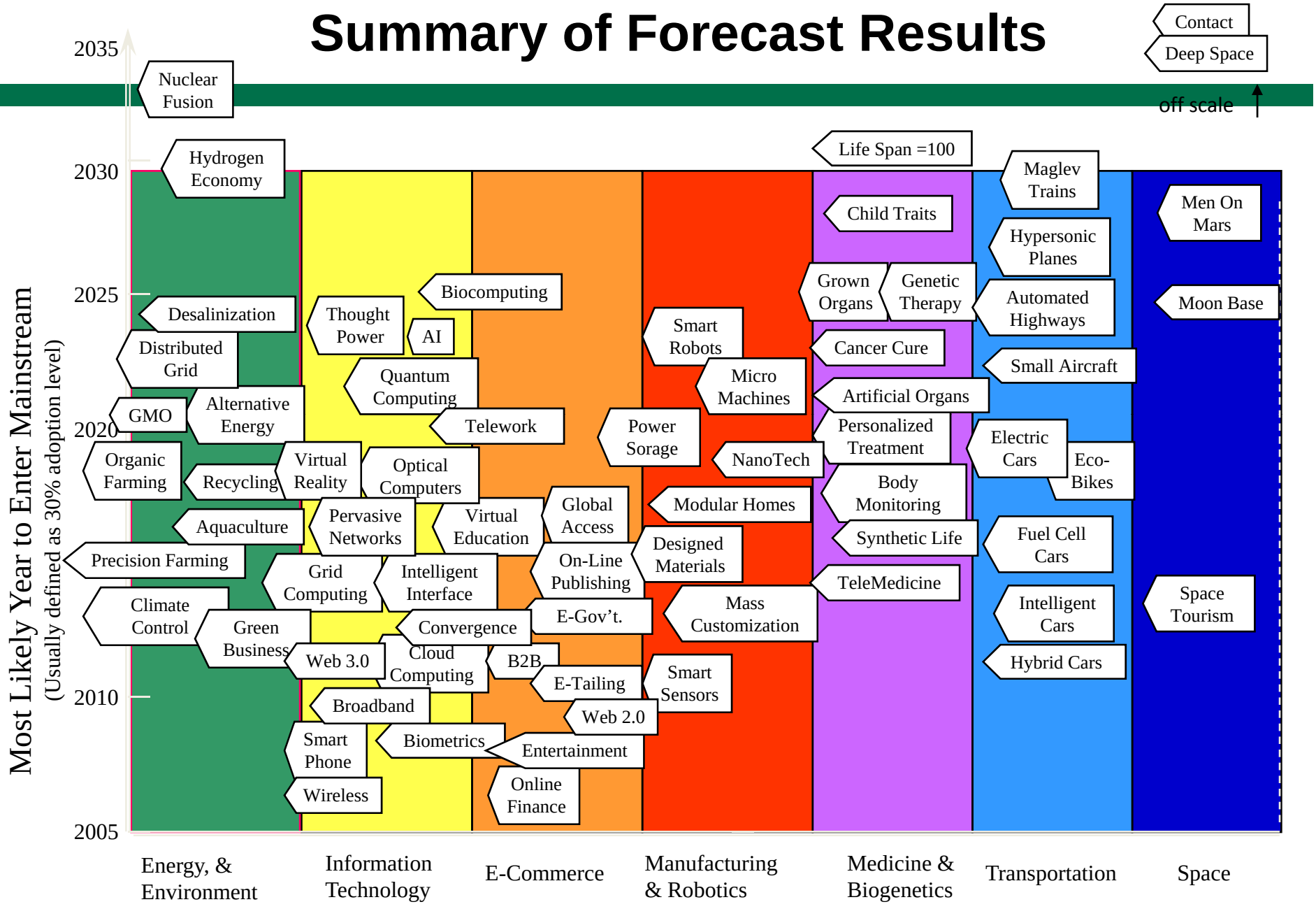
Summary of Forecast Results



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Delphi Method

- **Pros**
  - Opinion of Experts – Human beings
  - Larger the expert groups composition, opinions tend to even out biased opinions.

- **Cons**
  - Requires extensive research effort by the group
  - How does the expert group sift through multi-millions of references?
  - Multi-Language Databases

Approach adopted to zoom into most appropriate Software

- Survey revealed availability of 32+ software
- Generated a Market Investigation Questionnaire seeking responses.
- Conferred with sibling Army Organization who were already using a knowledge mining search, COTS software.
- Released the Market Investigation Questionnaire to the world by telephone/Internet.
- Received 4 responses.

Market Investigation Questionnaire

- 32 Questions (partial list given) with 9 categories in total
  - Content Capabilities
  - Search / Navigational Capabilities
  - Semantic Validation
  - Language Capabilities
  - Assessment and Forecasting
  - Licensing
  - Customer Base
  - Technical Specifications
  - Training / Technical Support

Market Investigation Questionnaire (continued)

- Partial list of 32 questions
  - Does the software provide access to the relevant worldwide scientific databases?
  - Is the tool able to navigate and browse world-wide patent databases?
  - Is the tool able to automate failure mode effects analysis (FMEA) and to automatically search and retrieve indexed content that pertains to known failure modes, their effects and causes?

Market Investigation Questionnaire (continued)

- Partial list of 32 questions (continued)
  - Is the tool able to search, index and summarize data in English, German, Japanese and French?
  - What are the costs and various types licensing available?
  - Who uses your product for systems engineering or complex process/manufacturing technology?

Principles of & Approaches to Software Knowledge/Data Mining

- Advent of Artificial Intelligence and Natural Language Processing have yielded Technology Advances.
- Over the last 3 decades, evolved from Statistical to Semantic Knowledge Mining, Assessment and Forecasting Solutions.
- Primarily 2 Major Approaches
  - Pattern-Cluster Recognition of Data
  - Semantic Search Engine

Principles of & Approaches to Software Knowledge/Data Mining

- **Pattern Recognition**
  - Uses the Search Engine resident within the World-wide Science Databases.
  - Through Refinement, pare down the number of applicable references.
  - Import the References into the Knowledge/Data Mining Software for further Analyses through Pattern Recognition of Data Clusters.
- **Semantic Search Enables**
  - Use of Natural Language Queries from World-wide Knowledge/Databases.
  - Identifies and generates **summaries** of the most relevant references.
  - Serves as **Virtual Subject Matter Expert**
  - Enables Science based Decisions for anything

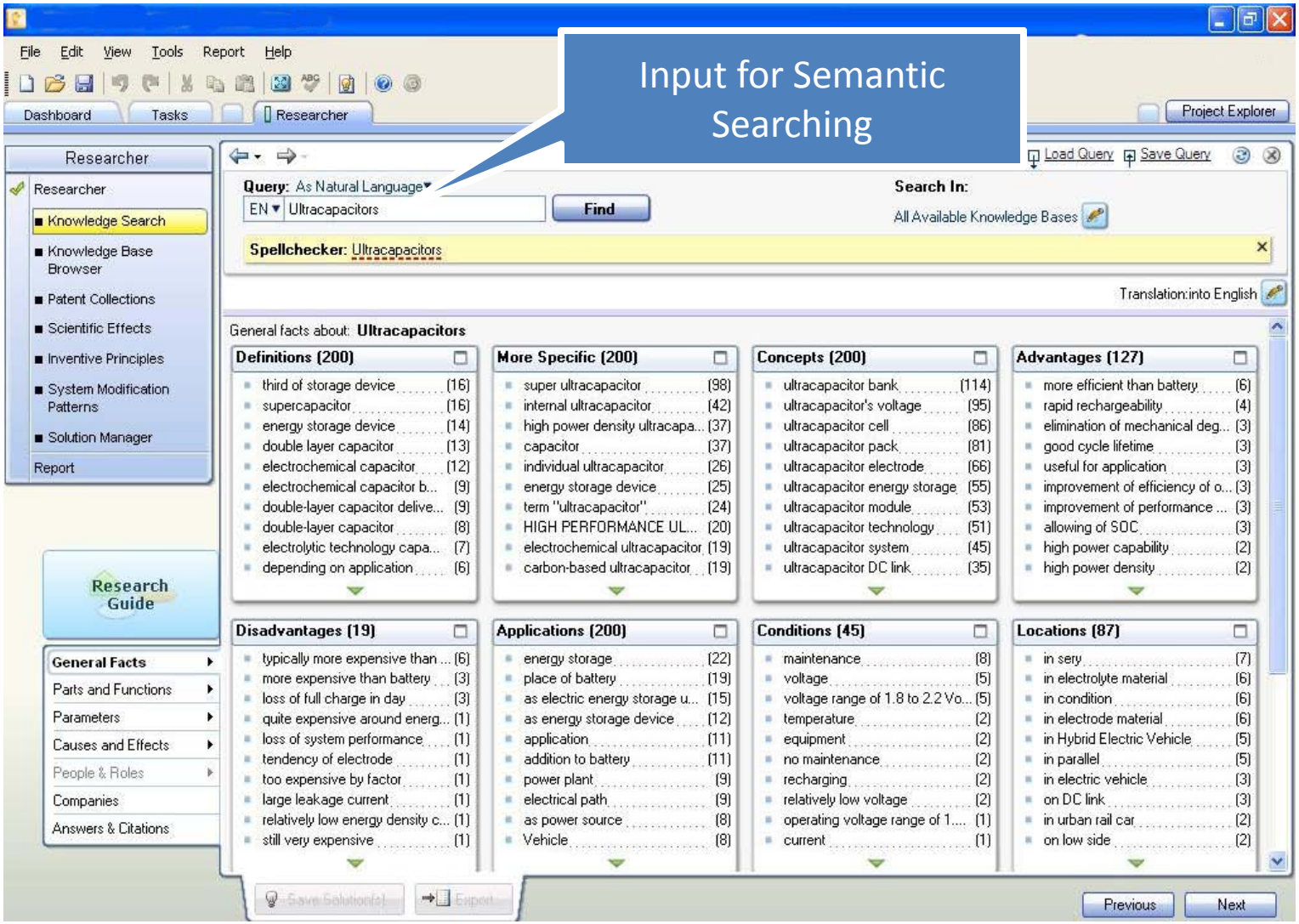
Comparison of Pattern Recognition Versus Semantic Search Software

Pattern Recognition	Semantic Search
- Requires structural text database, (e.g. Patent Records). - Requires subscription to world-wide databases, costly. - Need to know exact keywords for search. - May not access multi-language databases.	- Accesses both structured and unstructured databases. - Does not require actual subscription. - Yields dynamic summaries and NOT abstracts. - Accesses multi-language databases. - Virtual SME - Software helps to formulate the semantic search questions.

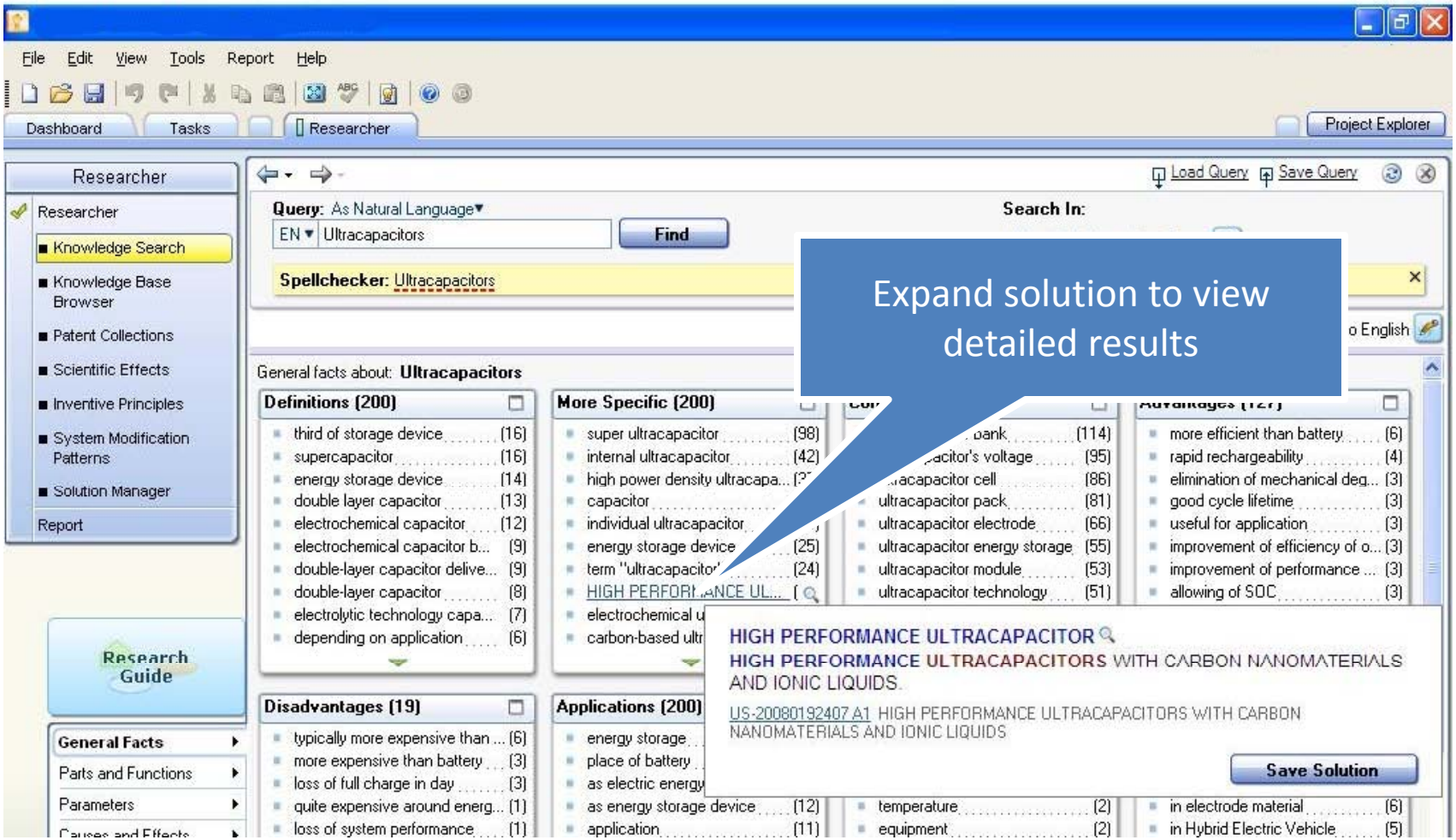
Semantic Technology Software Architecture

- Core Components Integration
  - Semantic Engine
  - Natural Language Processing
- Semantic Engine
  - Transforms information to an index of semantic terms
- User Queries via Natural Language Processing
  - Analyzed to compare user queries and source documents.

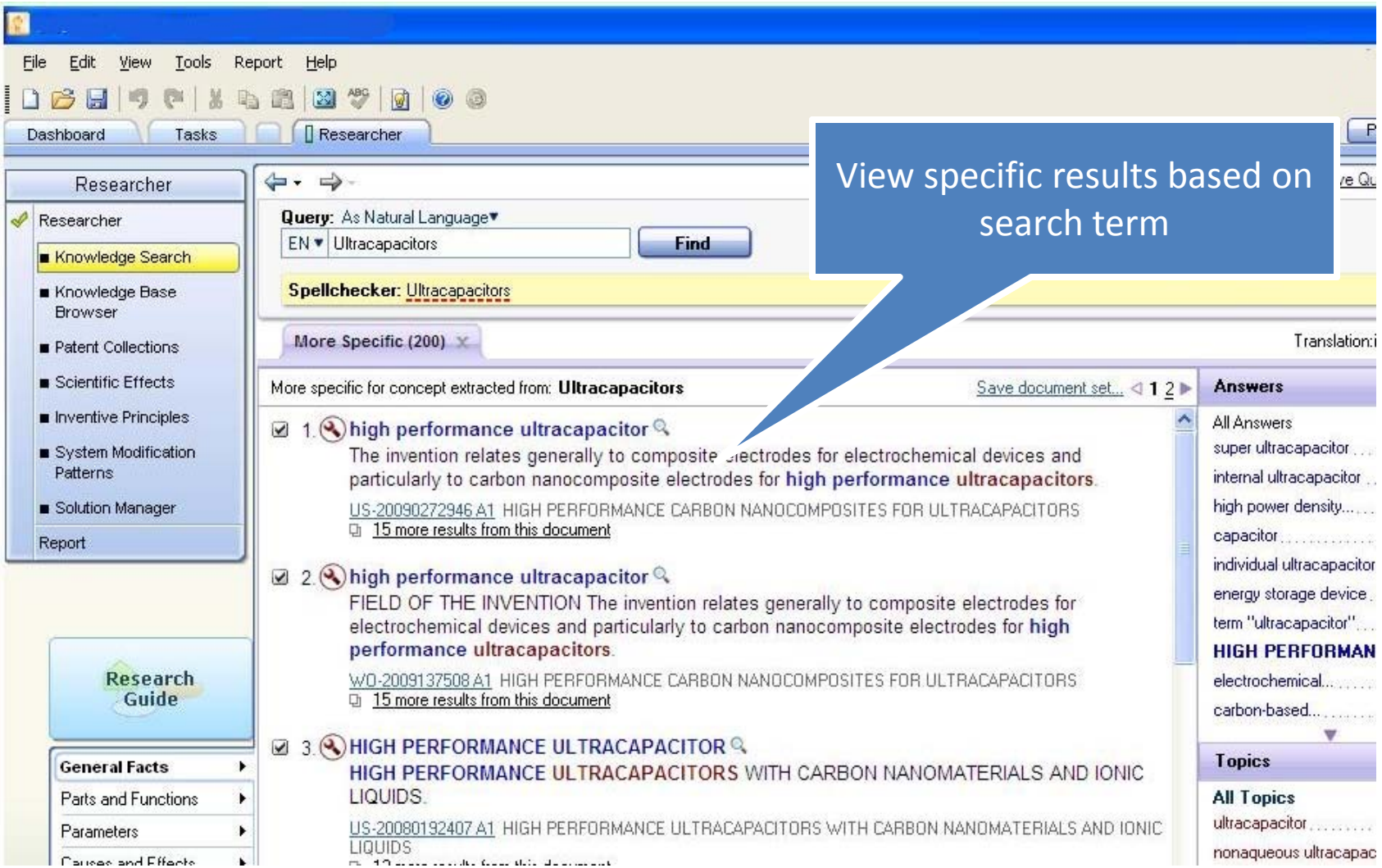
Semantic Technology Software Steps



Semantic Technology Software Steps

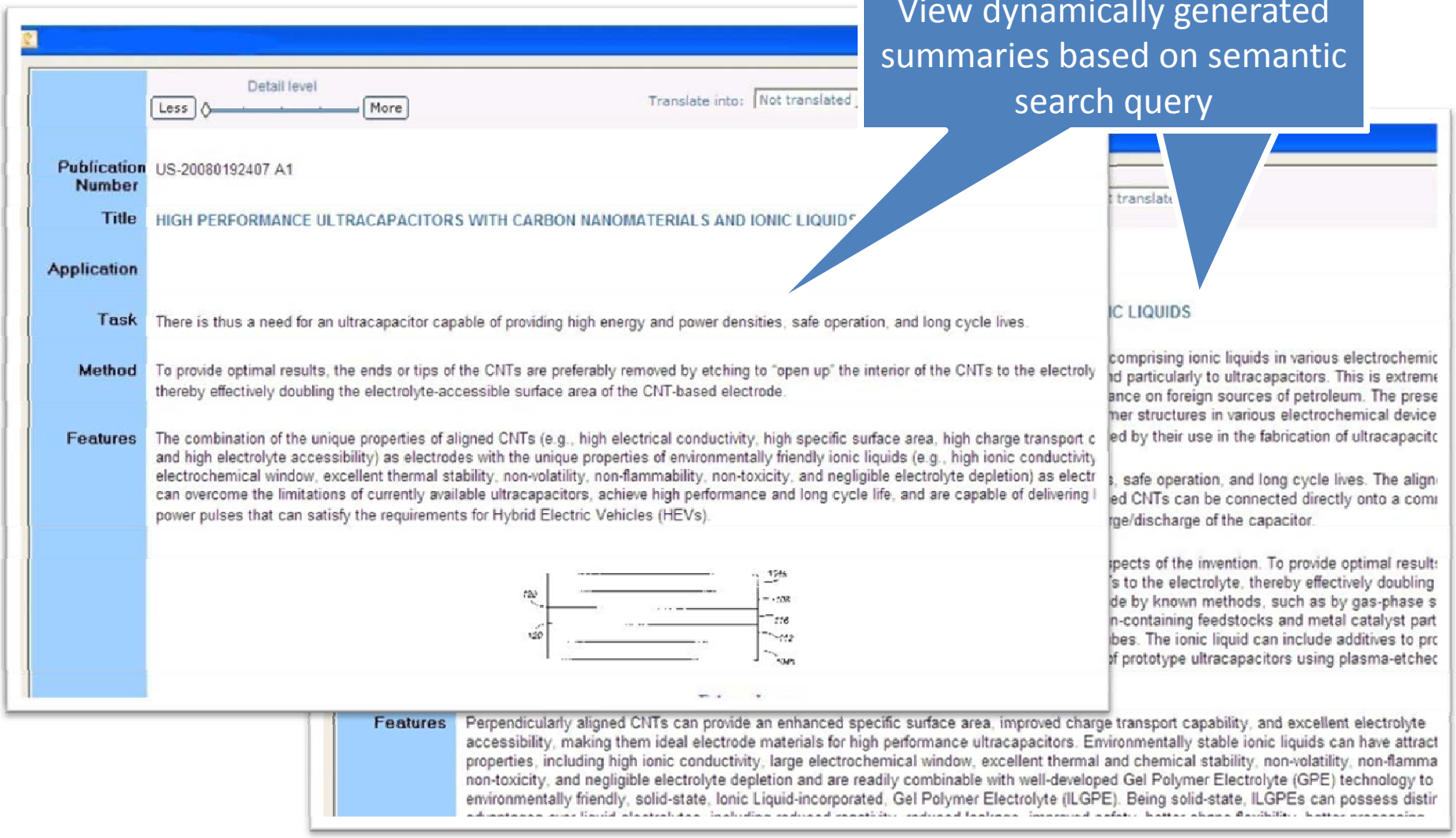


Semantic Technology Software Steps



Semantic Technology Software Steps

View dynamically generated summaries based on semantic search query

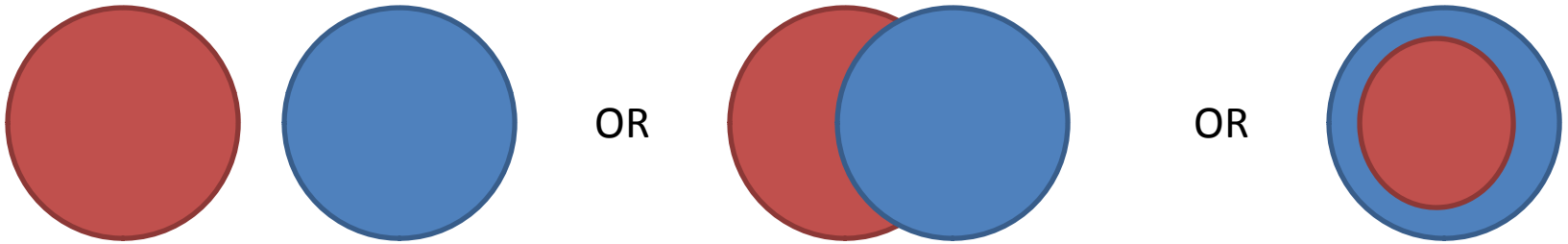


Semantic Search Knowledge Mining Versus Popular Internet Search Engine

Popular Internet Search	Semantic Search
- Information resides on internet company's servers. - Does not generate summaries - Requires subscription to databases, for access to articles.	- Accesses both structured and unstructured databases. - Does not require actual subscription. - Yields dynamic summaries - Accesses multi-language databases. - Virtual SME - Software helps to formulate the semantic search questions.

Implementation to Knowledge Mining, Assessment, and Forecasting Method for DELPHI and Software

- Both DELPHI and Semantic Searches - Expected Results



Case 1 **Case 2** **Case 3**

Red = DELPHI Method
Blue = Semantic Search Method

Technology Assessment Board (TAB) - Case Study

- XYZ, Inc. seeks Capital Investment Proposal
- **Proposal** from Hot Shot Scientist – Miniaturized Communication Antenna using Super-Conducting Materials.
  - Traditional Approach
  - Scientist briefs Corporate Board of Directors and requests $10 Million.
  - Board's Response and Questions – None, since they understood nothing on the technology.
  - Funding unanimously granted, since proposal sounded hi-tech
  - Funding not based on sound scientific principles

TAB Composition for the Miniaturized Superconducting Communications Antenna

- Basic Physicist for Superconductivity
- Ceramics Engineer for the Superconducting Materials
- Cryogenics Expert – Material Sciences
- Communications Specialist with Army Background
- System Integrator
- NASA
- Partners to Transition Technology to the Commercial World Applications.

Truly a Diverse, based on VIRTUAL SME, Technology Assessment Board (TAB) to Cost-Effectively decide Science based Investment Decision

Implementation Challenges and Mitigation Approach

- It is one thing to invent and another to disseminate
- Many people do not like **CHANGE**
- Each System encompasses Multiple Sciences and Engineering Disciplines
  - Multi-disciplinary TABs
- Technology is Rapidly Changing throughout the World
  - Semantic search will help

Implementation Challenges and Mitigation Approach

- Limited Budgetary Resources with Multiple Technologies Competing for the same.
  - TARDEC strategy to combine software semantic search with TAB
- Experienced Personnel in Military Systems Development Exponentially Decreasing through Retirements.
  - Employ young minds through a Co-op Program / SMART Scholars
- Pros and Cons of Central versus De-centralized Resident Experts in Knowledge/Data Mining within TARDEC.
  - Take one step at a time to enable and excite user market

Current Status

- Semantic Search based COTS software under Acquisition.
- Disseminate Program at every available opportunity.
- It seems the job was specifically created for me
- It seems that I was born to contribute my mite to technology.

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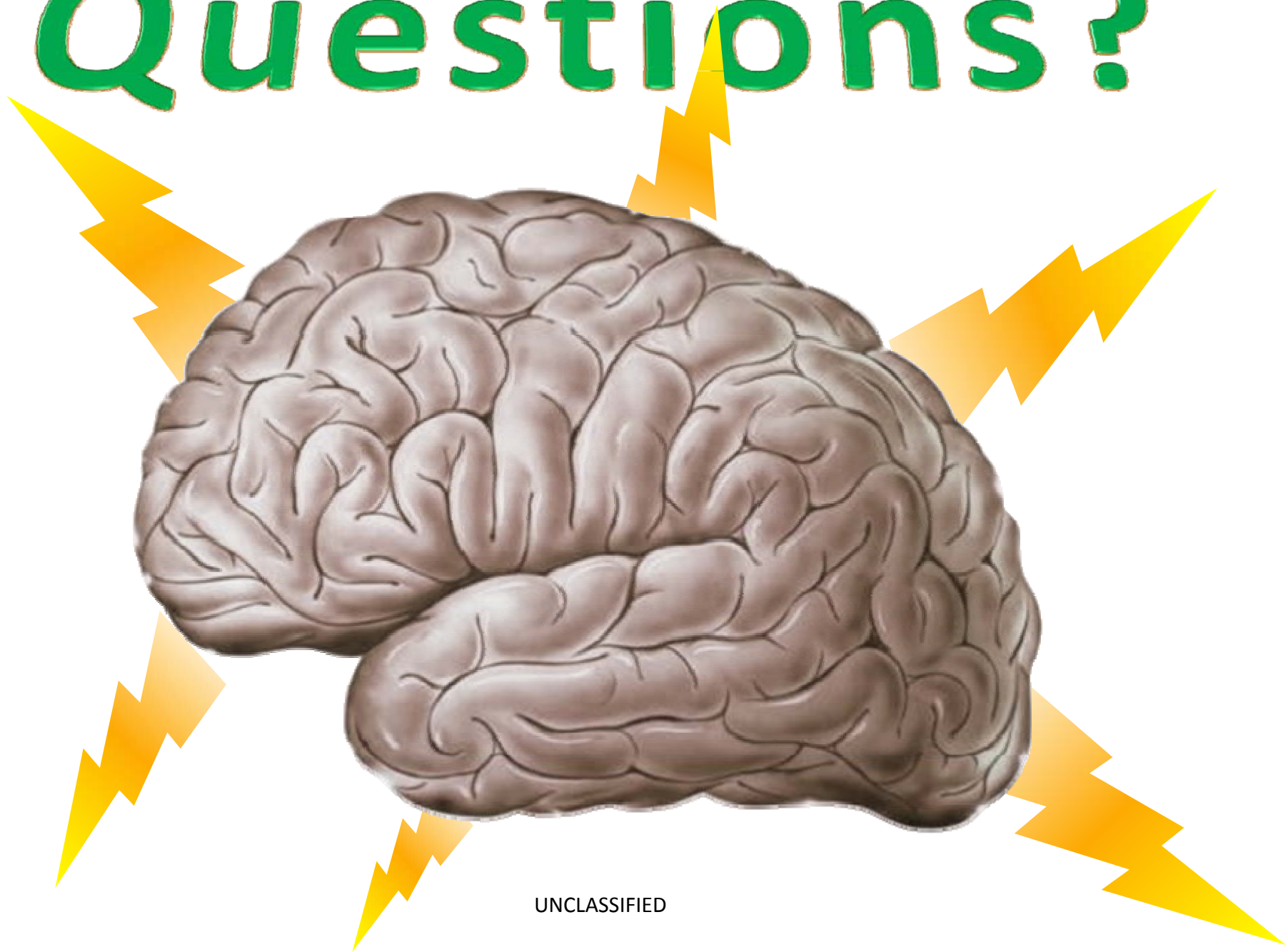
Technology, and Innovation at a leading U.S. university

Questions?



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